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| **Application No:** | GB 0020418.0 | **Examiner:** | Bill Riggs |
| **Claims searched:** | 1 - 9 | **Date of search:** | 14 March 2001 |

J1017 U.S. PTO 09/931041 08/17/01

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H2A (ARJ10, ART4); G1N(A) NAEA

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Other: Online databases: EPODOC, JAPIO, WPI

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB 1563605 | (Hitachi Ltd) see particularly figs. | 1 |
| A | US 4914713 | (Siemens AG) see whole document | |
| X | US 4082968 | (Contraves-Goertz Corp.) see particularly col.2 ll.10 - 16, col.4 ln.15 - col.5 ln.6 and figs.2 - 5 | 1 |

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| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

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# PATENT SPECIFICATION

(11) 1 563 605

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## (54) ELECTRIC MOTOR HAVING FREQUENCY GENERATOR

(71) We, HITACHI, LTD., and JAPAN SERVO CO., LTD., both corporations organized under the laws of Japan of 5-1, 1-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan and 7, Mitoshirocho, Kanda, Chiyoda-ku, Tokyo, Japan respectively, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to electric motors having a frequency generator capable of producing a signal having a frequency proportional to the speed of revolution and, more particularly, to electric motors used for disk record players, magnetic tape recorders of magnet tape players, which motor can produce a signal representative of the speed of revolution, which signal in turn is utilized in the speed control of the motor.

In disk record players or in magnetic tape recorders and players, the disk or the tape is strictly required to be correctly moved at a predetermined speed. Any change in the moving speed would cause a frequency modulation of the reproducing signal, whixch undesirably results in a flutter or a wow.

To avoid this drawback, in the recording or reproducing apparatus having a turn table or a capstan directly driven by a motor, the speed of revolution of the motor must be maintained constant.

It is a conventional measure to convert the revolution speed of the motor or the change in the revolution speed into a signal having variation in frequency, voltage or capacitance, which signal is compared with a reference signal representative of a correct revolution speed, thereby to correct the revolution speed proportional to the difference produced in comparison with the reference signal.

Hitherto, several approaches have been proposed and used for detecting the revolution speed of a motor.

One of them employs a magnet carried by the rotor for revolution therewith and a generator coil disposed to oppose to the magnet so that the magnetic flux may intersect the coil thereby to produce a signal of a frequency proportional to the revolution speed. This arrangement has been found, however, inconvenient in that the size of the structure becomes unacceptably large, due to the additional provision of the magnet on the rotor, especially when the number of poles of the magnet or the number of the coil is increased for obtaining a signal of a high frequency. Such a large motor is impractical for use in disk record players or magnetic tape recorders of the like in which a number of parts are housed by a cabinet of a limited size.

Another means for detecting the revolution speed of a motor employs an optical means including a disk carried by the rotor. The disk is provided with a number of peripheral equispaced slits. A light source such as a lamp is disposed at one side of the disk, while a light-sensitive equipment such as a photo transistor is disposed at the other side, so that the light passing through the slits may generate a signal of a frequency which is in proportion to the revolution speed, at the light-sensitive equipment. This arrangement has been found also unsatisfactory, due to the complicated structure of the motor, especially when the number of slits and/or the light source is increased to obtain a signal of a higher frequency.

Clearly, The higher frequency of the revolution speed signal provides the more accurate speed control of the motor when the speed control is effected using the revolution speed signal. In addition, it is preferred that the motor does not prduce electric and mechanical noises which would badly affect the electronic instrument which

is highly sensitive even to a weak signal.

It is therefore an object of the invention to provide an electric motor which is flattened in shape and reduced in size and has a frequency generator capable of detecting the change in the revolution speed as a change in frequency.

According to the invention, there is provided an electric motor incorporating a frequency generator comprising a rotary shaft, a disk-shaped multipolar magnet having a plurality of magnetizable sectors, said sectors being magnetized to exhibit poles of difference polarities at both thicknesswise ends, adjacent ones of said sectors being poles of reverse polarities, a pair of flat driving coils disposed parallel with and spaced from said magnet and within a field of said magnet, and a flat speed detecting coil disposed parallel with and spaced from said magnet and within a magnetic field of said magnet, said driving coils and said speed detecting coil being arranged to be nonrotatable, each of said driving coils having a plurality of driving portions interlinking with magnetic flux of said magnet, said speed detecting coil having $2n + 1$ radially extending generating conductive strips corresponding to each one of said magnetic poles, where $n$ is a positive integer, said conductive strips being serially-connected, whereby said speed detecting coil acts as a frequency generator producing a signal having a frequency corresponding to speed of rotation of said magnet, when said driving coils are supplied with electrical power.

The electric motor is flattened and small-sized, due to the adoption of the disk-shaped multipolar magnet. At the same time, the provision of a number of generating conductive strips for each magnetic pole of the magnet provides a signal of high frequency, which conveniently ensures the detection of even a small change in the revolution speed.

The invention will become more clear from the following detailed description of preferred embodiments of the invention, when taken in conjunction with the accompanying drawings, in which:

*Figure 1* is a partially sectioned perspective view of an electric motor having a frequency generator and embodying the present invention;

*Figure 2* is an exploded view of the motor of Figure 1;

*Figure 3* is a perspective view of a speed detecting coil; and

*Figure 4* is an exploded view of a disk magnet and the speed detecting coil.

Referring at first to Figures 1 and 2, an electric motor 1 has a disk-shaped base plate 2 of a magnetic material such as ferro or silicon steel plate and a cup-shaped upper cover 3 mounted on the base plate. The upper cover 3 consists of an upper plate 4, a cylindrical portion 5 connected to the upper plate and an annular rim 6 which are all made of a magnetic material. The base plate 2 is adapted to play the role of a lower yoke and has at its mid portion cylindrical bearing 7. The bearing 7 is made of a non-magnetic material such as brass and is provided with an upper peripheral rim 8, and is inserted into a cental opening 9 of the base plate 2 until the lower surface of the rim 8 comes in contact with the upper surface of the base plate 2. The bearing 7 has a threaded lower end 10 onto which is screwed a cap 11 accommodating a ball bearing 12 adapted to carry a rotary shaft 13 inserted into the bearing 7 from its upper side. Thus, the rotary shaft 13 is rotatably supported by the bearing 7 and by the ball bearing 12.

The rotary shaft 13 carries at its mid portion an upper yoke 14 made of a magnetic material, such as ferro or silicon steel, to the lower surface of which is secured by means of an adhesive a disk-shaped multipolar magnet 15. The magnet 15 is made of a magnetic material such as an alloy of aluminum, nickel, and cobalt or ferrite and has a central opening 16 through which passes the rotary shaft 13. Thus, the magnet 15 is secured to the upper yoke 14 concentrically with the rotary shaft 13. The magnet 15 is circumferentially sectioned to have a plurality of sections, eight sections in the illustrated embodiment. The adjacent sections are differently magnetized. For example, a section 17 is magnetized to become N pole at the upper surface of the magnet 15, while the sections 18, 20 adjacent to the section 17 are magnetized to become S poles. The sections 19 next to the section 18 is accordingly magnetized to N. Each section 17, 18, 19 ..... is magnetized in its thicknesswise direction so as to exhibit different polarities at the upper and lower surfaces thereof. For instance, supposing that the upper surface of the section 17 is magnetized to N, the lower surface is magnetized to S.

Four washers 21 are disposed on the upper surface of the base plate 2. The washers 21 carry an insulation plate 22 made of a phenol resin or a like material having a central opening 28 receiving the bearing 7. The insulation plate 22 is secured to the base plate 2, defining therebetween a certain gap provided by the washers 21, by means of screws 24 screwed into threaded bores 25 of the base plate 2 through bores 23 formed at the corners of the insulating plate 22 and through respective washers 21.

A pair of driving coils 26, 27 are secured to the lower surface of the insulating plate 22, each of which consists of a number of fine copper wires having outer insulative

layers, which wires being wound in the shape of a star. More strictly, the star-shaped winding is made by bending the wire at successive inner and outer points for a number of repeated turns, four outer points being defined on a circle having a diameter equal to that of the magnet 15, while four inner points being defined on another circle having a diameter equal to that of the inner periphery of the magnet 15, the inner points being rotated through 45° from the outer points. The driving coils are superimposed one on the other concentrically with the driving shaft 13 and are secured to the insulation plate 22 by means of an adhesive.

Each of the coils 26, 27 has driving wire elements extending from the inner periphery to the outer periphery of the coil, or vice versa, which intersect the fluxes of the magnet 15, the portions of intersection constitute driving portions 29, 30 for driving the magnet 15. Thus, the driving portions contain driving wire elements extending toward the outer periphery from the rotary shaft 13. The coils 26, 27 are superimposed one on the other such that their driving portions 29, 30 form therebetween an angle of 22.5°.

A plurality of radially extending generating conductive strips 31 are formed on the upper surface of the insulation plate 22 and are connected in series to form a speed detecting coil 50. Thus, as seen from Figure 3, the speed detecting coil 50 comprises a plurality of radially extending generating conductive strips 31, 32, 33, 34, 35 ..... formed on the upper surface of the insulation plate 22. The first conductive strip 31 is connected to an adjacent second conductive strip 32 at its inner end, while the second strip 32 in turn is connected at its radially outer end to a third strip 33. The third strip 33 and a fourth strip 34 are connected to each other at their inner ends. The adjacent conductive strips are connected in series in the described manner.

The speed detecting coil 50 can advantageously be formed by printing. To this end, a copper foil is secured onto the surface of the insulating plate 22 on which formed are the strips 31, 32, 33 ..... and their connecting portions by means of printing. Then, the foil is subjected to a corrosion process with the printed portion being covered, so that the uncovered portion may be corroded. The number of the conductive strips 31, 32, 33 ..... is, for each magnet pole of the magnet 15, $2n + 1$, where $n$ is a positive integer. The embodiment of Figure 3 has 24 conductive strips in total, three strips for each one of the eight magnet poles, i.e. $n$ equals to 1, while in the embodiment of Figure 2, $n$ equals to 4, since 72 strips are provided, 9 for each one of the eight magnetic poles.

The first conductive strip 31 and the last conductive strip 35 (the 24th element in Figure 3) are provided with terminals 36, 37 to which are connected lead wires to form output terminals of the speed detecting coil 50.

The cup-shaped upper cover 3 has an opening 38 at the center of its upper plate 4, in which is inserted the upper end of the rotary shaft 13. The upper cover has a rim 6 which is in contact with an secured to the base plate 2 by screws 39.

The rotary shaft 13 has a pointed upper end adapted to play the role of a central shaft for a turn table carrying a record disk, when the motor is used for driving a disk record player.

In operation, a sine-wave alternating current is supplied to each of the driving coils 26, 27. More strictly, there is a phase differential of 90°, between the current supplied to the coil 26 and the current supplied to the coil 27. Accordingly, magnetic fluxes are produced around the copper wires forming the coils 26, 27, among which the fluxes generated by the driving portions 29, 30 intersect the magnetic fluxes provided by the poles 17, 18, 19 ..... 20 of the magnet 15, so as to impart to the latter a torque effective to rotate the magnet 15 clockwisely.

Supposing here that direct currents are supplied to the coils 26, 27, a negative torque is generated at certain portions of rotation, since the adjacent magnetic poles are reversely magnetized. However, no reversing torque results, since the coils 26, 27 are in fact, supplied with respective alternating currents. Thus, the magnet 15 is allowed to rotate smoothly in one direction.

The torque imparted to the magnet 15 is a function of the angular position of the magnet 15, i.e. sine of the angle of rotation. In the described embodiment, the coils 26, 27 are rotated through 22.5° from each other. As aforementioned, the coil 27 is supplied with an alternating current which has a phase differential of 90° with respect to the alternating current for the coil 26. In other words, while the coil 26 is supplied with a sine-wave alternating current, the coil 27 is supplied with a sine-wave alternating current. These angular differential and the phase differential in combination provide a constant torque imparted to the magnet 15.

As the magnet 15 rotates, the magnetic fluxes generated by the magnetic poles 17, 18, ..... 20 rotate intersecting the generating conductive strips 31, 32, .... 35 of the speed detecting coil 50, inducing signals of voltage corresponding to the change in flux densities and of frequency corresponding to that of the change. The signal is induced in the conductive strip passed by the gaps between the magnetic poles 17, 18, ..... 20. Since the

conductive strips are 2n + 1 in number for each magnetic pole of the magnet 15, the signal generated in the conductive strips are conveniently synchronized and are arithmetically added to form a current flowing in one direction.

Figure 4 shows a relationship, in an exploded illustration, between the signal generated in the conductive strips in the speed detecting coil 50 and the magnetic poles. Figure *4a* shows an arrangement in which *n* equals 1, i.e. three conductive strips for each magnetic pole, while Figure *4b* shows an arrangement having five conductive strips for each magnetic pole, i.e. *n* being 2.

Referring to Figure 4*a*, three conductive strips 31, 32, and 33 correspond to the magnetic pole 18, while another three conductive strips 34, 41 and 42 correspond to the magnetic pole 19. Supposing that the magnet 15 moves in the right-hand side direction, as shown by an arrow, as viewed on Figure 4, the strip 31 disposed confronting the gap between the poles 17, 18 which has intersected the magnetic flux of the magnetic pole 18 comes to intersect the flux provided by the pole 17. This change in the direction of the magnetic flux produces a voltage in the strip 31. Meanwhile, no voltage is induced in the other strips 32, 33, since they are not subjected to the change in the magnetic flux. The polarity of the voltage induced in the strip 31 is supposed here to provide a current which flows upwardly as designated by an arrow, a downwardly flowing current is induced in the strip 34 which is disposed confronting the gap between the magnetic poles 18 and 19. For the same reason, at the same time, an upwardly flowing current and a downwardly flowing current are generated in the strips 43 and 44, respectively, which elements being disposed between the poles 15, 20 and between the poles 20, 40, respectively. It will be understood that the resulting currents are of the same flowing direction and can be arithmetically added as an output signal. Similarly, in the arrangement of Figure 4*b*, voltages of the same polarity are induced in the strips 31, 42, 43 and 44, resulting currents of same direction of flow in the speed detecting coil 50. Since the arrangement of Figure 4*a* has a larger number of conductive strips that the arrangement of Figure 4a, a correspondingly higher frequency of the signal is obtained.

Each generating conductive strip intersects successive magnetic fluxes, as the magnet 15 rotates, so that the resulted frequency of the output signal is in proportional to the speed of revolution of the magnet 15.

It will be seen that eight magnetic poles simultaneously detect the revolution speed, so that the fluctuation in magnetization of the poles and the minor deviations of the poles are conveniently negated to provide a correct measuring of the revolution speed.

The frequency of the output signal is then compared with a frequency of a reference signal, the resulted differential is utilized in raising or lowering the voltages of the alternating current supplied to the driving coils 26, 27, thereby to maintain the revolution speed constant. Alternatively, the output frequency from the speed detecting coil 50 is transduced to a voltage which is then compared with a reference voltage to provide a control input for regulating the revolution speed of the magnet 15.

It will be clear from the foregoing description that there has been provided an electric motor having a magnet constituting a rotor and being adapted to detect the revolution speed of itself, which renders the speed control accurate, in spite of the small-sized and simplified structure. The motor can be sufficiently flattened by the adoption of a disk-shaped magnet and a thin driving coil. In addition, a remarkably high frequency of output signal is obtained through the adoption of a number of generating conductive strips which are conveniently formed by means of printing at a high dimensional accuracy. The motor does not employ a commutator nor a brush which would produce unfavourable noises, since sine-wave alternating current is effectively used for driving the motor.

WHAT WE CLAIM IS:

1. An electric motor incorporating a frequency generator comprising a rotary shaft, a disk-shaped multipolar magnet having a plurality of magnetizable sectors, said sectors being magnetized to exhibit poles of difference polarities at both thicknesswise ends, adjacent ones of said sectors being poles of reverse polarities, a pair of flat driving coils disposed parallel with and spaced from said magnet and within a field of said magnet, and a flat speed detecting coil disposed parallel with and spaced from said magnet and within a magnetic field of said magnet, said driving coils and said speed detecting coil being arranged to be nonrotatable, each of said driving coils having a plurality of driving portions interlinking with magnetic flux of said magnet, said speed detecting coil having 2n + 1 radially extending generating conductive strips corresponding to each on of said magnetic poles, where *n* is a positive integer, said conductive strips being serially connected, whereby said speed detecting coil acts as a frequency generator producing a signal having a frequency corresponding to speed of rotation of said magnet, when said driving coils are supplied with electrical power.

2. An electric motor as claimed in claim 1, wherein said driving portions of said driving coils consist of a plurality of driving wire elements extending from the centers of said driving coils toward their peripheries, said driving portions being adapted to impart a driving torque to said magnet upon receipt of an alternating electric power, said driving coils being rotatably positioned with respect to one another so that their driving portions form an angle of 22.5 degrees therebetween.

3. An electric motor as claimed in claim 1 or 2, wherein one of said pair of driving coils is supplied with a driving a.c. current of sine wave producing at the driving portions thereof a driving magnetic field interlinking with the magnetic flux of said magnet for driving said magnet, and the other of said pair of driving coils is supplied with a driving a.c. current of cosine wave producing at the driving portions thereof a driving magnetic field interlinking with the magnetic flux of said magnet for driving said magnet.

4. An electric motor as claimed in claim 1, 2 or 3, wherein said speed detecting coil comprises a printed coil in which said generating conductive strips extend in a radial direction thereof and are connected in series with each other.

5. An electric motor as claimed in any preceding claim, wherein the speed detecting signal of said speed detecting coil is used for controlling of the rotational speed of said magnet.

6. An electric motor as claimed in any preceding claim, wherein said magnet is provided with 8 magnetic poles, each of which is magnetized in its thicknesswise directions.

7. An electric motor as claimed in any preceding claim, wherein said first and second driving coils are respectively star-shaped, each being provided with 8 driving portions.

8. An electric motor as claimed in any preceding claim, further comprising: a first yoke made of a magnetic material; a bearing secured to said first yoke; a rotary shaft rotatably supported by said bearing; a second yoke secured to said rotary shaft and spaced from and opposite to said first yoke; and an insulating plate disposed between said first yoke and said second yoke and secured to said first yoke; said magnet being secured to said second yoke and spaced from said first yoke and adapted to rotate with the rotation of said rotary shaft and said second yoke, and said driving coils and said spaced detecting coil being mounted on said insulating plate.

9. An electric motor constructed and arranged to operate substantially as hereinbefore described with reference to and as shown by the accompanying drawings.

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1563605 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

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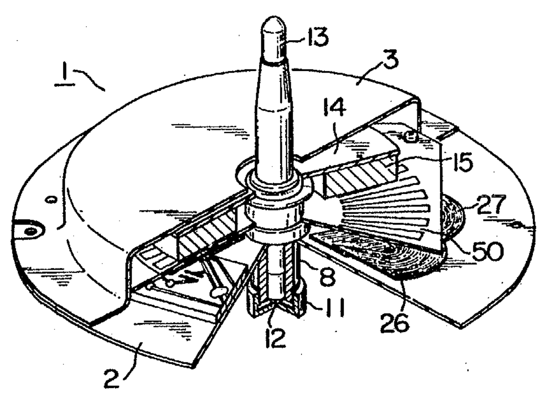

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**Sheet 2**

FIG. 2

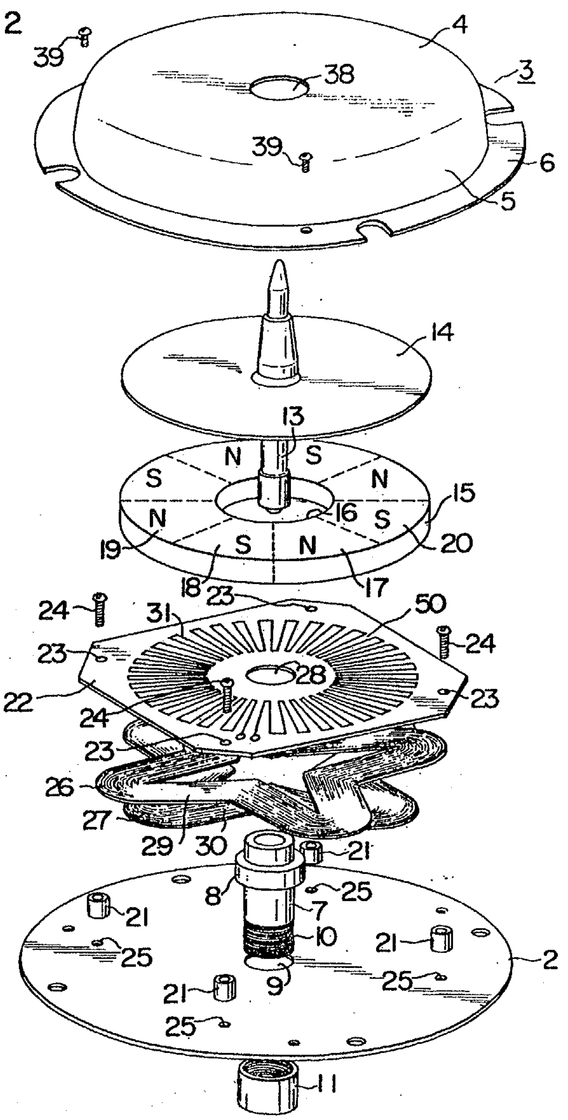

FIG. 3

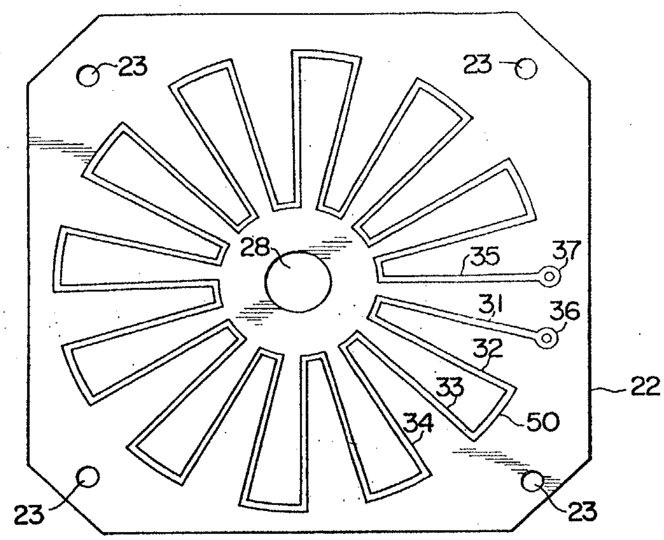
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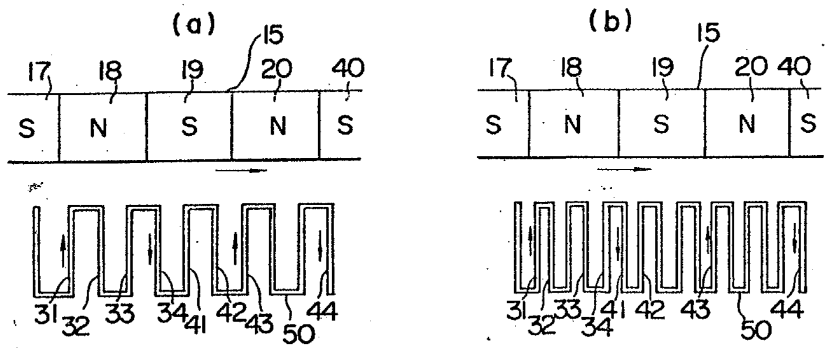
FIG. 4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